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COMPUTATIONAL STRUCTURAL MECHANICS: A NEW ACTIVITY AT THE NASA LANGLEY RESEARCH CENTER

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COMPUTATIONAL STRUCTURAL MECHANICS: A NEW ACTIVITY AT THE NASA LANGLEY RESEARCH CENTER

Norman F. Knight, Jr. and W. Jefferson Stroud

INTRODUCTION

Computational mechanics is that discipline of applied science and engineering devoted to the study of physical phenomena by means of computational methods based on mathematical modeling and simulation, utilizing digital computers (ref. 1). The discipline combines theoretical and applied mechanics, approximation theory, numerical analysis, and computer science. Computational mechanics has had a major impact on engineering analysis and design. The application of computational mechanics to contemporary problems in engineering involves the sequence of steps identified in reference 1. The sequence of steps is as follows:

1. Observation of the phenomena of interest;

2. Identification of a mathematical model;

3. Validation of the mathematical model;

4. Development of the computational algorithm;

5. Development and/or assembly of computer hardware;

6. Interpretation of computed results; and

7. Utilization of the results in the analysis and design of engineering systems.

Within this general framework, computational mechanics is being used today in a broad range of engineering applications. When applied to structural mechanics, the discipline is referred to herein as computational structural mechanics.

Complex structures being considered by NASA for the late 1980's and early 1990's include composite primary aircraft structure and the space station. These structures will be much more difficult to analyze than today's structures and necessitate a major upgrade in computerized structural analysis technology. NASA Langley has initiated a new research activity in structural analysis called Computational Structural Mechanics or CSM. The broad objective of the CSM activity is to develop advanced structural analysis technology that will exploit modern and emerging computers--such as computers with vector and/or parallel processing capabilities.

NASA LANGLEY'S CSM ACTIVITY

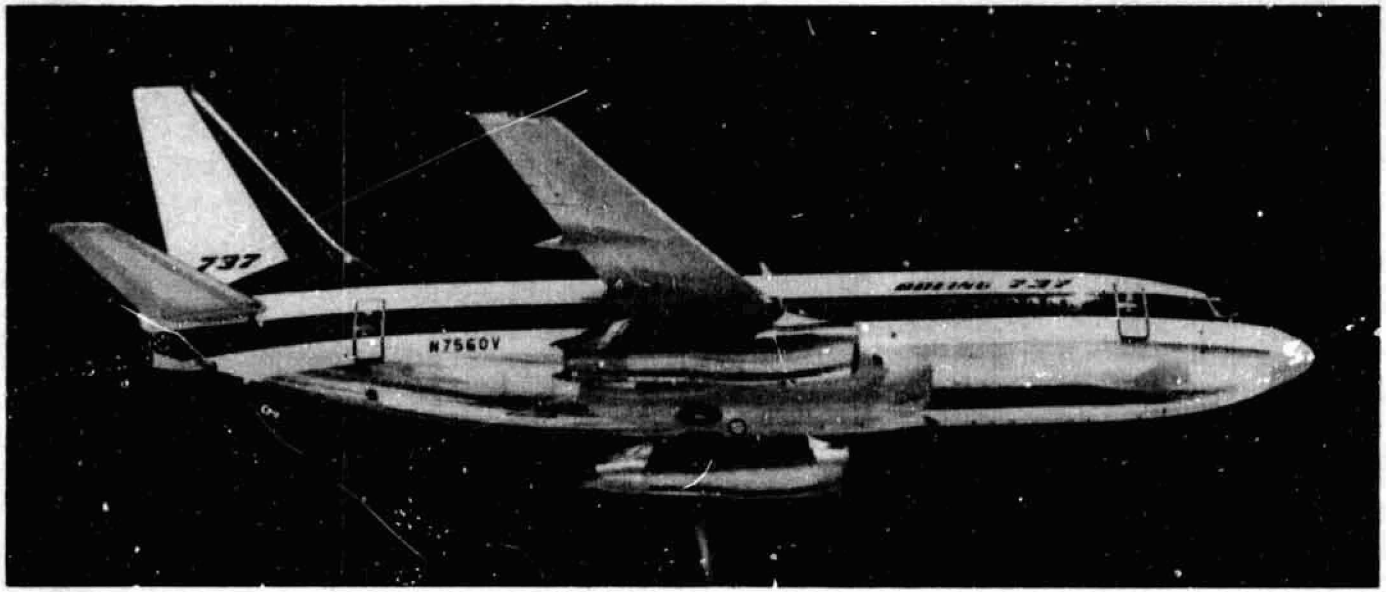
- Motivation and objectives
- Description of CSM activity
- Research thrusts

NASA LANGLEY'S CSM ACTIVITY

NASA Langley's CSM activity is a result of a major agency commitment to advance computerized structural analysis technology. The CSM group of the Structural Mechanics Branch was formed in October 1984. The motivation and objectives of the CSM activity are presented in this paper followed by a description of the CSM activity. The three main research activities underway in CSM include: (1) structural analysis methods development, (2) a software test bed for evaluating the methods, and (3) numerical techniques for parallel processing computers. Finally, the current CSM research thrusts, as well as near- and long-term CSM research thrusts, are outlined.

STRUCTURAL ANALYSIS PROBLEMS

Commercial/military transport aircraft



Problem areas
- Composites
- Discontinuities
- Windows, doors, holes, damage
- Buckled skin
- Routine detailed analysis

Accurate and reliable analytical tools will lead to:
- Reduced testing needs
- Reduced weight associated with high margins for uncertainty
- Improved performance

STRUCTURAL ANALYSIS PROBLEMS
COMMERCIAL/MILITARY TRANSPORT AIRCRAFT

This slide indicates structural analysis problems for commercial/military transport aircraft. These problems occur in metal as well as composite structures. However, the brittle nature of composites requires that their strength limits and failure characteristics be well understood before composite structural components can be designed properly. In many respects, a greater need for reliable and accurate analytical predictive techniques exists for composite structures than for metal structures. The difficulties associated with analyzing composite structures are magnified when there are discontinuities such as free edges, bolt holes, and bonded joints. Other problems are caused by windows, doors, access holes, and damage.

To save weight, many designers are proportioning structural panels so that the skin can buckle in service. Such panels are lighter than buckling-resistant panels. However, analyzing the postbuckling response of these structurally efficient composite panels is very difficult with today's analysis procedures. Specifically, it can be computationally difficult to track the postbuckling response; it can be frustrating and time consuming to have numerous restarts; and it can be expensive.

The problem of calculating detailed stress distributions around discontinuities in buckled, composite structural components for use with the various analytical failure prediction techniques has not been thoroughly explored. Because of the complex failure modes of composite structures, it may be necessary to perform a detailed 3-D stress analysis in a local region in order to obtain an adequate estimate of the strength. Today, carrying out such an analysis of a composite component can be a major research task. The capability to carry out, on a routine basis, a local 3-D stress analysis of a composite component within a larger 2-D analysis model is needed.

Accurate and reliable structural analysis procedures will lead to reduced time and cost for testing, reduced weight penalty associated with high margins for uncertainty, and improved performance.

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STRUCTURAL ANALYSIS PROBLEMS

Advanced aerospace vehicles

Adaptive structures
Thermal structures
Damage tolerant structures
Advanced structural concepts
Advanced material systems

→ Increased demands on analysis methods, computational techniques, computing technology →

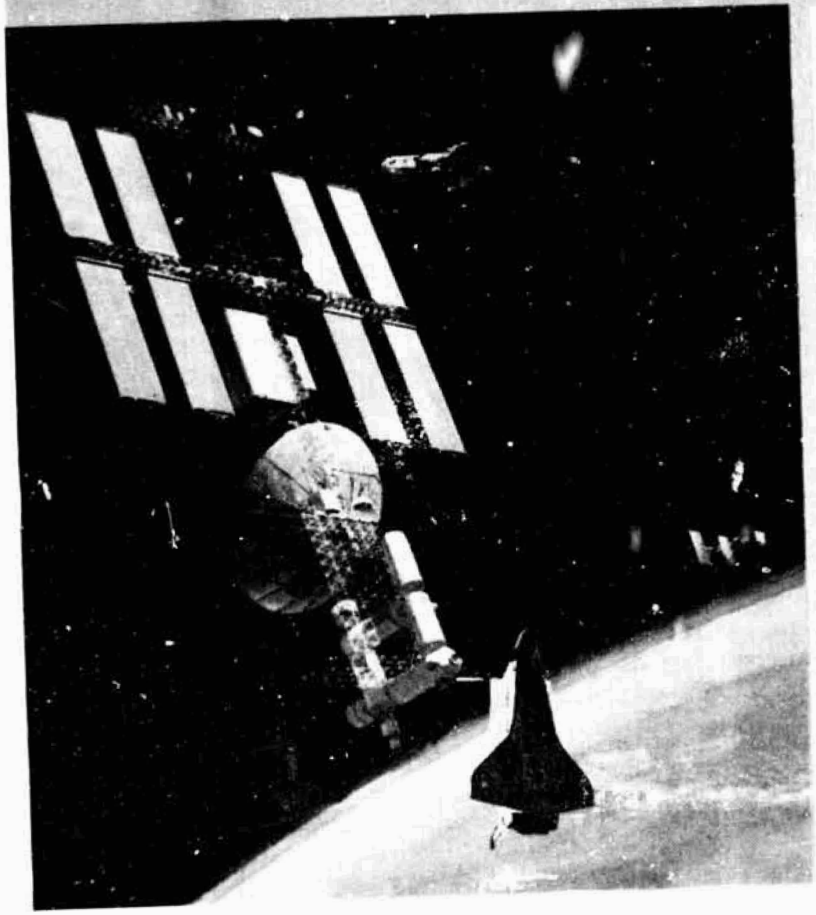
Shuttle II
ATF
TAV

STRUCTURAL ANALYSIS PROBLEMS
ADVANCED AEROSPACE VEHICLES

New technology research thrusts for advanced aerospace vehicles can result in significant increases in payload, weight reduction, range and speed, maneuverability, fuel efficiency and safety. Important structural technology thrusts include adaptive structures, thermal structures, and damage-tolerant structures designed using advanced structural concepts and material systems. To obtain significant advancements in these technology thrusts requires increased demands on structural analysis methods, on computational techniques, and on the computing environment.

STRUCTURAL ANALYSIS PROBLEMS

Large space structures



Problem areas

- Deployment dynamics of realistic space structures
- Nonlinear transient response of flexible multibody structural systems that are typical of space station

Accurate and reliable analytical tools will lead to:

- Improved performance
- Reduced testing needs
- Enabling technology - some tests cannot be performed in 1-G environment

STRUCTURAL ANALYSIS PROBLEMS
LARGE SPACE STRUCTURES

An important analysis problem for space structures is the dynamic analysis (including transient analysis) of large structural systems composed of many flexible, interconnected components. The dynamic excitation of these flexible systems is caused by maneuver, deployment, and robotic manipulation. Large kinematic motions and friction in joints can cause the dynamic response of these systems to be nonlinear. Analysis procedures for treating this class of problems need to be more robust, reliable and efficient. The assessment of deployment analysis methods given in reference 2 indicates that analytical methods to design each deployment concept (e.g., extension, assembly and unfolding) are needed and that a general approach usable for a variety of deployment methods would be most cost effective. Comparisons could then be made between different deployment concepts or under different simplifying assumptions using a consistent theoretical approach, and evaluation of concepts would be more direct.

Accurate and reliable structural analysis procedures lead to reduced time and cost for testing and improved performance. In many cases, improved analysis is an enabling technology because some tests on space structures cannot be carried out in a 1-G environment. Because of these testing limitations, there will be greater reliance on computer analysis (simulation) in the design of space structures than in the design of earth-based structures.

STRUCTURAL ANALYSIS NEEDS

- Major improvements needed in:
  - Analytical formulations
  - Computational techniques
  - Modeling
  - Error analysis
  - User interface
- Software that incorporates above improvements
- Account for major advances in computer hardware
  - Multiprocessor computers

STRUCTURAL ANALYSIS NEEDS

To solve the structural analysis problems discussed on the three previous slides, major improvements are needed in structural analysis technology. Furthermore, the technology must be incorporated in software that accounts for a changing computer environment--perhaps a radically changing environment.

Analytical formulation refers to basic theories in structural analysis, such as new approaches to define nonlinear and transient problems and new finite element representations. Computational techniques refer to the solution strategies used to solve the structural analysis problem. Whereas most linear and static structural analysis problems can be solved using almost any modern solution strategy, success in solving most nonlinear or transient structural analysis problems requires robust computational procedures and trained, qualified analysts. The selection of a solution procedure is perhaps the most important factor in performing a nonlinear analysis. Often, the selection of an efficient solution procedure may allow the analyst to use an adequate mathematical model of the structure and obtain an accurate prediction of the structural response. The selection of an inefficient solution procedure may force the analyst to compromise the mathematical model of the structure to the point that the accuracy of the computed results may be questionable. With improved analytical models and computational techniques, nonlinear transient analyses and 3-D nonlinear stress analyses should become routine calculations.

The last three technologies listed in the slide--modeling, error analysis, and user interface--are related. These technologies deal with rapid and reliable definition of the mathematical model of the structural analysis problem and the interpretation of computed results. The structural analyst should define the analysis problem and prescribe the accuracy of the desired results. Error analysis coupled with other logic should automatically choose the finite element or finite difference grid size (or, for time-dependent problems, the time step) to give the prescribed accuracy.

The needed technology improvements listed in the upper part of the slide should be incorporated in structural analysis software, and that software should account for advancements in computer hardware such as new array processors, supercomputers, and computers with parallel/concurrent processing. In particular, future scientific computers will have a parallel processing capability. An appropriate match of structural analysis software and computer hardware could provide a substantial increase in computational speed.

CSM OBJECTIVES

- Identify, develop, and extend structural analysis and computational methods that have high potential
- Develop a standard generic software system test bed for structural analysis
- Develop advanced structural analysis and computational methods that exploit advanced computer hardware

CSM OBJECTIVES

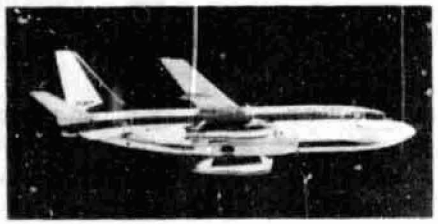
The first objective is to identify, develop and extend structural analysis and computational methods that have high potential for solving critical application problems and for removing analysis deficiencies. Structural applications and analysis deficiencies drive the methods development and the application of these methods should provide new insight for complex, nonlinear structural mechanics problems. The analysis and computational methods should be amenable to error analysis. That is, given a physical problem and a mathematical model of that problem, an analyst would like to know the probable error in predicting a given response quantity. The ultimate goal is to specify the error tolerances and to use automated logic to adjust the mathematical model or solution strategy to obtain that accuracy. Iterative rather than direct methods may have to be used for this type of problem even if the structural analysis problem is linear.

The second objective is to develop a standard test bed software system for structural analysis. The test bed is to be a modern, modular system that handles data efficiently, that contains a command language which is powerful and easy to learn and use, and that has an architecture which allows users to add software with minimal difficulty. The test bed is a framework for studying ingredients of modern software and how those ingredients should fit together and for evaluating structural analysis methods on practical applications problems. The test bed software system should serve as a system for technology development leading to an improved understanding of the physical behavior of a structure for researchers as well as a system for solving practical engineering problems for typical engineers.

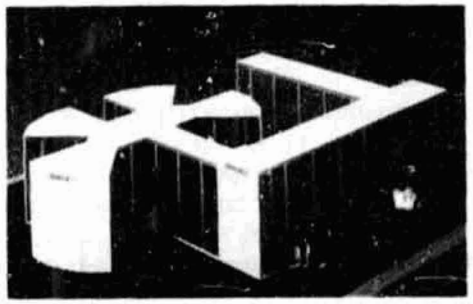
The third objective is to develop structural analysis and computational methods that exploit advanced computer hardware. This activity involves an ongoing research activity in parallel processing that uses an experimental, in-house-developed multiprocessor computer known as the Finite Element Machine or FEM (refs. 3 and 4) and, in addition, uses a new commercially-available multiprocessor computer known as the FLEX/32 (ref. 5). High performance computers of the future will have multiple processors, and software approaches and structural analysis algorithms to exploit this new capability are being developed (e.g., refs. 6-9).

COMPUTATIONAL STRUCTURAL MECHANICS

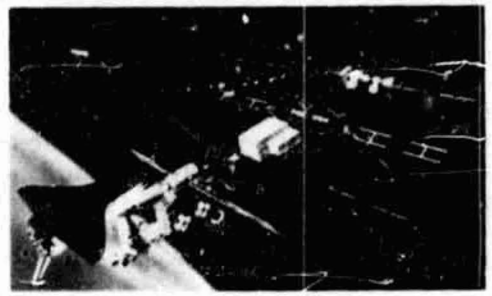
Aircraft Structures



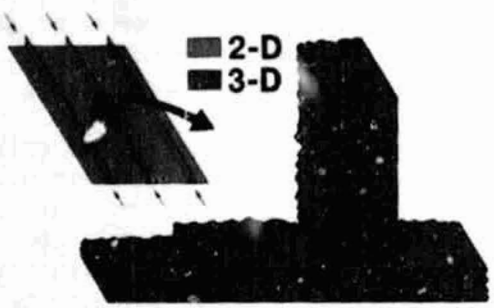
Advanced Architecture Computers

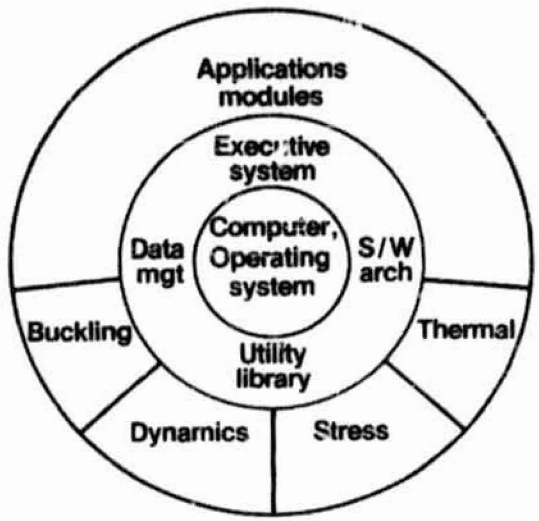


Space Structures

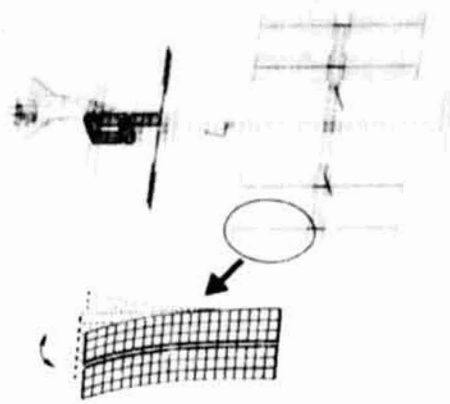


Local 3-D nonlinear stress analysis within larger 2-D analysis model





Transient Dynamics



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COMPUTATIONAL STRUCTURAL MECHANICS

The overall objective of the CSM activity is to develop the computational structural mechanics technology needed to analyze the complex aircraft and space structures of the 1990's. The development of the CSM technology and its transfer to the aerospace community will help the U.S. to maintain its preeminence in the field of aerospace.

A Cyber 200-class supercomputer similar to the VPS-32 at Langley is shown in the upper center figure. The computational efficiency on these machines depends dramatically upon the computational algorithm used and its implementation.

A standard generic test bed system is depicted in the lower center figure. The expanding level of capabilities and specializations emanate from a core containing the computer hardware and its operating system through an executive system containing engineering support utilities and a periphery containing application modules. The test bed serves as a vehicle to transfer proven analytical methods and computational algorithms to the aerospace industry.

The CSM activity will use several practical applications as targets. The first target is to develop the capability to carry out on a routine basis a local detailed 3-D stress analysis of a composite component within a larger 2-D analysis model. While developing that capability, several focus problems will be solved, the first of which is a stiffened composite panel with a discontinuous stiffener, as indicated in the lower left portion of the figure. The second target is still being defined. The development of an improved capability to calculate the transient dynamic response of multibody space structures as shown in the lower right portion of the figure is currently being considered along with other targets.

Software to address these focus problems will be developed and will be available to researchers for subsequent use. In the case of the detailed stress analysis example, the new capability will allow researchers to study stress distributions associated with failure so safer and more efficient structures can be designed. In the case of the dynamic analysis example, the new capability will allow researchers to predict the dynamic response of the space station.

The methods research activity is similar in many respects to our current base research and technology program except at an expanded level. It involves grants, contracts, visiting scientists, and NASA researchers. During the first years, the scope of the methods research activity will be focused on applied structural mechanics research to insure that analysis methods with high potential for solving critical application problems and for removing analysis deficiencies are identified and to accelerate the methods technology transfer to industry.

TECHNOLOGY DEVELOPMENT FOR FUTURE STRUCTURAL ANALYSIS SYSTEM

The program in perspective

Technology development program

- Methods research
- Test beds for evaluating new methods and new hardware concepts

Output

- Proven software incorporating new analysis methods
- Definition of future structural analysis system

Payoff

- Ability to handle our current analysis problems
  - Detailed stress analysis of composite structures
  - Transient dynamic analysis of space structures
- Ability to develop next generation structural analysis system

TECHNOLOGY DEVELOPMENT FOR FUTURE STRUCTURAL ANALYSIS SYSTEM
THE PROGRAM IN PERSPECTIVE

The CSM program has two elements: (1) methods research and (2) test beds for evaluating new methods and new hardware concepts. The first program element involves methods research in structural analysis as well as methods research in numerical analysis for advanced architecture computers. The second program element involves a structural analysis software test bed for evaluating new analytical methods and computational algorithms and also, a computer hardware test bed for evaluating advanced computer architectures and their asynchronous computational capabilities. The combination of these two program elements will provide proven software and the definition of a future structural analysis system. The software will provide the capability to handle current analysis problems as well as those problems likely to occur through the early 1990's and will provide a vehicle to transfer the technology to industry. The system definition will provide specification and requirements for the development of the next generation structural analysis system.

CURRENT CSM RESEARCH THRUSTS

(6 to 12 months)

- Build and enhance initial CSM software test bed system - NICE/SPAR

- Solution strategies for nonlinear mechanics
  - Local/global methodologies
  - Transient analysis

- Parallel processing
  - Transition from FEM to FLEX/32
  - Install NICE/SPAR on FLEX/32
  - Concurrent sparse matrix utilities

<u>Application studies</u>

Blade-stiffened G/E panel with discontinuous stiffener

Curved composite panels with and without holes

CURRENT CSM RESEARCH THRUSTS
(6 TO 12 MONTHS)

During the next 6 to 12 months, the CSM group will focus on three tasks. The first task is to build the initial CSM software test bed system. An initial test bed software system will consist of the NICE executive system and data manager (ref. 10) coupled with the structural analysis computer code SPAR (ref. 11). Additional analysis modules are being developed, and documentation is being written (ref. 12). This initial system, denoted NICE/SPAR, will be available to interested users for evaluation, and recommendations from users will be considered as the system is enhanced.

The second task, methods research, is focusing primarily on solution strategies for nonlinear local/global stress analysis of composite structures. Current areas of research associated with local/global methodologies are described in references 13 and 14. Techniques for refined 2-D/3-D local detailed analyses are being developed and implemented. Continuation methods (e.g., ref. 15) and the equivalence transformation technique (e.g., ref. 16) will be implemented as runstreams or procedure-level solution strategies. Also, preliminary studies are planned in the area of nonlinear transient dynamics. Reviews of computational methods in transient dynamics are presented in references 17 and 18.

In the third task, structural analysis methods for parallel processing computers, the target computer will shift from the FEM (e.g., ref. 3) to the FLEX/32 computer (ref. 5). The most important goal in this task is to install the NICE/SPAR test bed on the FLEX/32 computer. The first step in that installation is to modify NICE/SPAR so that it will operate under UNIX, the operating system for the FLEX/32 computer. These modifications are underway. Additional research is underway to develop sparse matrix utilities so that NICE/SPAR can operate on the FLEX/32 in a concurrent mode.

The application studies during this period will focus on predicting the nonlinear local/global structural response of specific composite panels. One approach to uncovering the difficulties of this type of analysis and to providing specific directions for future research in this area is a direct attack on the problem using currently available analysis tools. A candidate problem has been selected and the next few slides describe experiences from calculating its structural response.

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BLADE-STIFFENED GRAPHITE-EPOXY PANEL WITH A DISCONTINUOUS STIFFENER

FOCUS PROBLEM

- Graphite-epoxy (T300/5208)
- Flat panel with three blade stiffeners
- 30 in. long
- 11.5 in. wide
- Stiffener spacing of 4.5 in.
- Stiffener height of 1.4 in.
- 2.0-in.-diameter hole
- 25-ply panel skin
- 24-ply blade stiffeners
- Axially loaded with loaded ends clamped and sides free

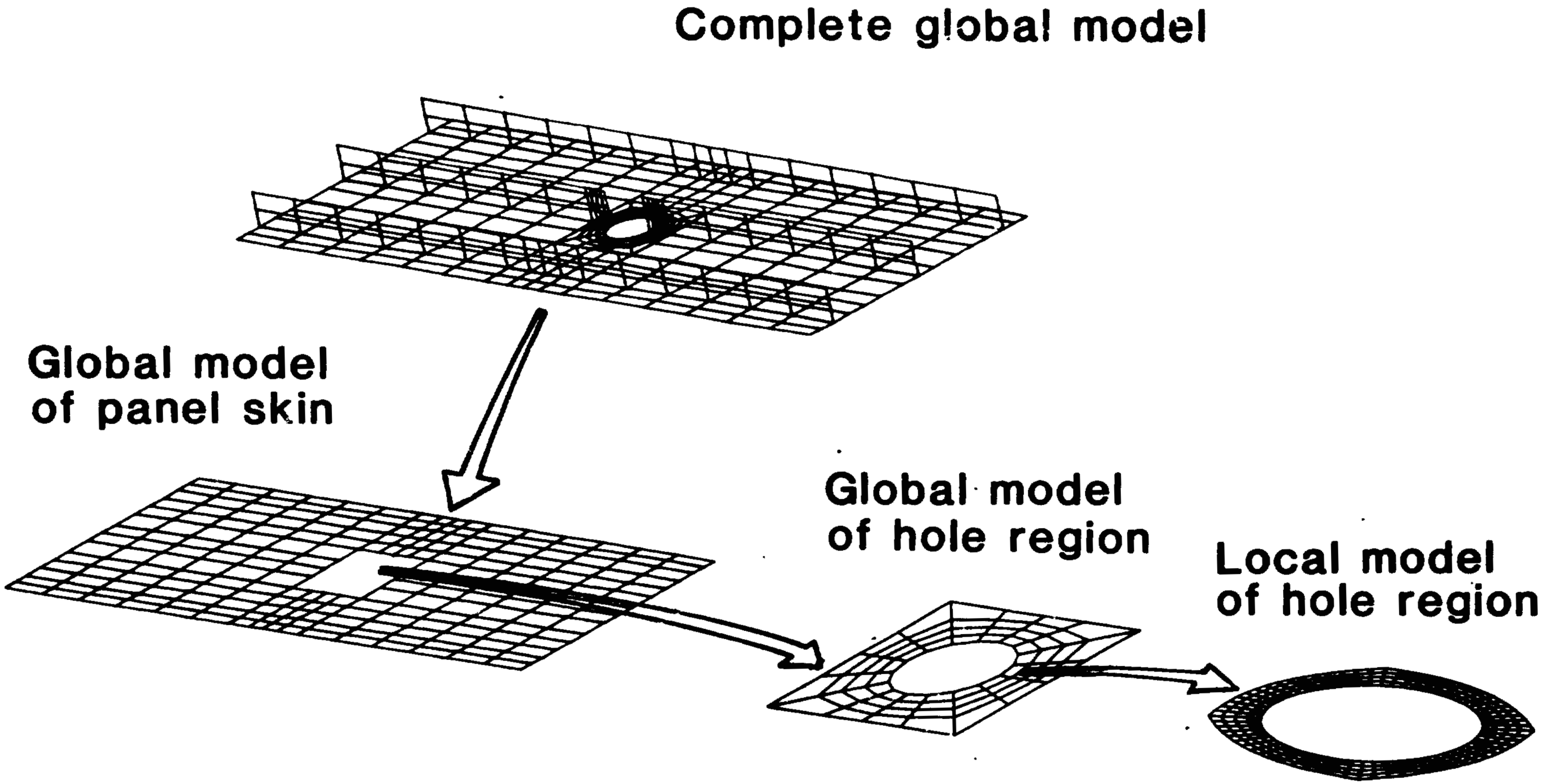
BLADE-STIFFENED GRAPHITE-EPOXY PANEL WITH A DISCONTINUOUS STIFFENER
- FOCUS PROBLEM -

Discontinuities and eccentricities are usually present in practical structures. In addition, potential damage of otherwise perfect structures is often an important design consideration. Predicting the structural response in the presence of discontinuities, eccentricities, and damage is particularly difficult when the component is built from graphite-epoxy materials or is loaded into the nonlinear range. Recent interest in applying graphite-epoxy materials to aircraft primary structures has led to several studies of postbuckling behavior and failure characteristics of graphite-epoxy structural components (e.g., refs. 19-21). However, these studies concentrated on two topics: understanding the physical behavior and predicting the overall response of composite structural components in the postbuckling range; or, identifying failure mechanisms and developing analytical failure prediction techniques for fibrous composite materials. The problem of calculating detailed stress distributions around discontinuities in buckled, composite structural components for use with the various analytical failure prediction techniques has not been thoroughly explored because of the general lack of 3-D interlaminar stress analysis capability in most nonlinear analysis codes.

A focus problem for local/global stress analysis is to determine the nonlinear response of a flat, blade-stiffened graphite-epoxy panel with a discontinuous stiffener. The material system for the panel is T300/5208 graphite-epoxy unidirectional tapes with a nominal ply thickness of 0.0055 in. Typical lamina properties for this graphite-epoxy system are 19,000 ksi for the longitudinal Young's modulus, 1,890 ksi for the transverse Young's modulus, 930 ksi for the shear modulus, and 0.38 for the major Poisson's ratio. The panel skin is a 25-ply $([\pm 45/0_2/\mp 45/0_3/\pm 45/0_3/\mp 45/0_3/\pm 45/0_2/\mp 45])$ laminate and the blade stiffeners are 24-ply $([\pm 45/0_{20}/\mp 45])$ laminates. The overall length of the panel is 30 in., the overall width is 11.5 in., stiffener spacing is 4.5 in., stiffener height is 1.4 in., and the hole diameter is 2 in. The loading is uniform axial compression. The loaded ends of the panel are clamped and the sides are free.

This problem is selected as a focus problem because it has characteristics which often require a local/global analysis and because experimental results are available to verify the analysis. These characteristics include a discontinuity, eccentric loading, large displacements, large stress gradients, high inplane loading, and a brittle material system. This problem represents a generic class of laminated composite structures with discontinuities in which the interlaminar stress state becomes important.

FINITE ELEMENT MODEL DEVELOPMENT



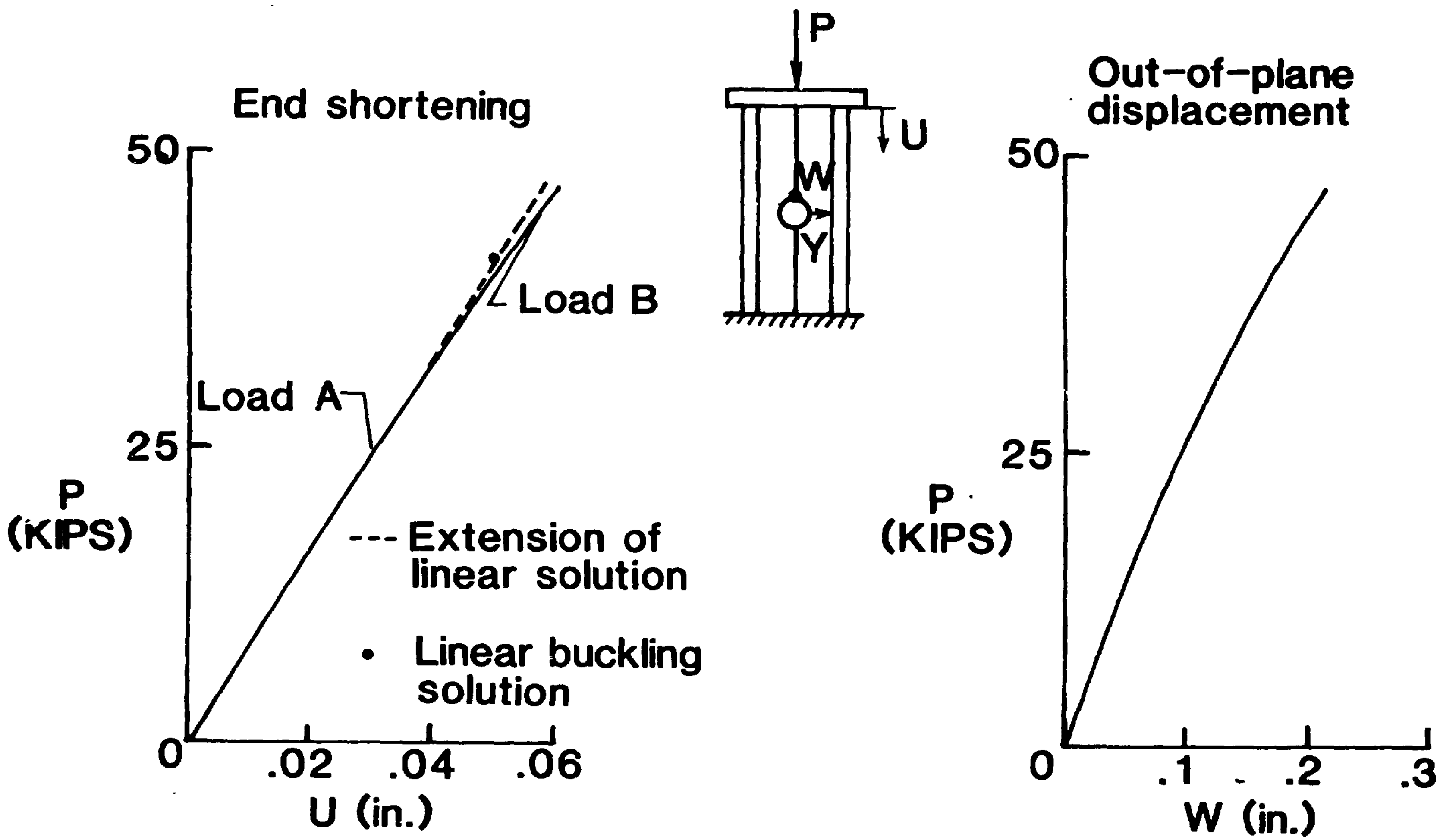
FINITE ELEMENT MODEL DEVELOPMENT

The local/global methodology adopted for this problem is the finite element method because of its generality. The first step in applying the method is to develop and verify a finite element model of the focus problem. Model verification involves solving simple example cases and comparing the results with other analytical results. This model verification process is aided by development of a flexible mesh generation capability which allows various finite element discretizations to be evaluated rapidly and systematically. The mesh generation capability also provides an easy way to construct and study idealized example cases.

The model development strategy is to predict the global nonlinear response using the complete, global 2-D model and then construct a refined, local 2-D model for a small distance away from the hole to predict accurately the large stress gradient. Displacements and rotations from the global nonlinear solution obtained using the complete model are applied to the refined model and the state of stress determined. This strategy is referred to as a multi-level or "zoom-in" approach. To establish the accuracy of the refined, local 2-D model near the hole, a 3-D model is analyzed and the stress state determined.

The automated mesh generation capability allows versatile modeling of the complete problem as well as local regions near the hole. The analyst specifies the number of elements across the stiffener depth and down the length of the panel, the number of rings of elements around the hole, the number of elements around the hole, and control the element spacing in the vicinity of the hole. Models can also be generated with the hole and discontinuous stiffener filled-in or with no stiffeners.

GLOBAL NONLINEAR RESPONSE PREDICTION



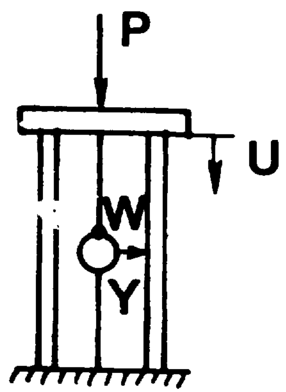
GLOBAL NONLINEAR RESPONSE PREDICTION

The global nonlinear response predicted for the focus problem is obtained using a new release of the finite element analysis system EAL (Engineering Analysis Language, ref. 22). This new release has a geometric nonlinear analysis capability using a corotational formulation with linear strain-displacement relations within the elements. For this problem, the loading is applied in increments with a full Newton-Raphson algorithm. The convergence criterion is based on the maximum error in the internal force vector. The finite element model of the focus problem has 376 4-node assumed-stress hybrid quadrilateral elements and 422 nodes. Comparison of linear bifurcation buckling results using various finite element grids is used to establish the adequacy of this model.

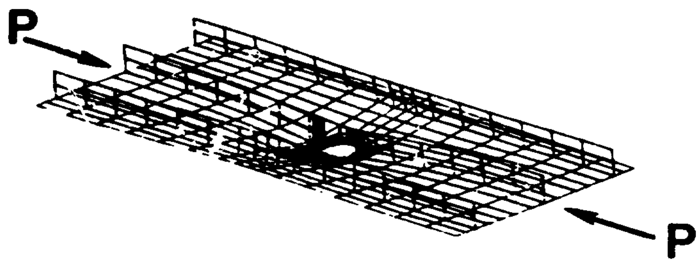
A global response quantity, end shortening, is nearly a linear function of the applied load. A local response quantity, out-of-plane displacement at the edge of the hole and blade stiffener, indicates large displacements from the onset of loading.

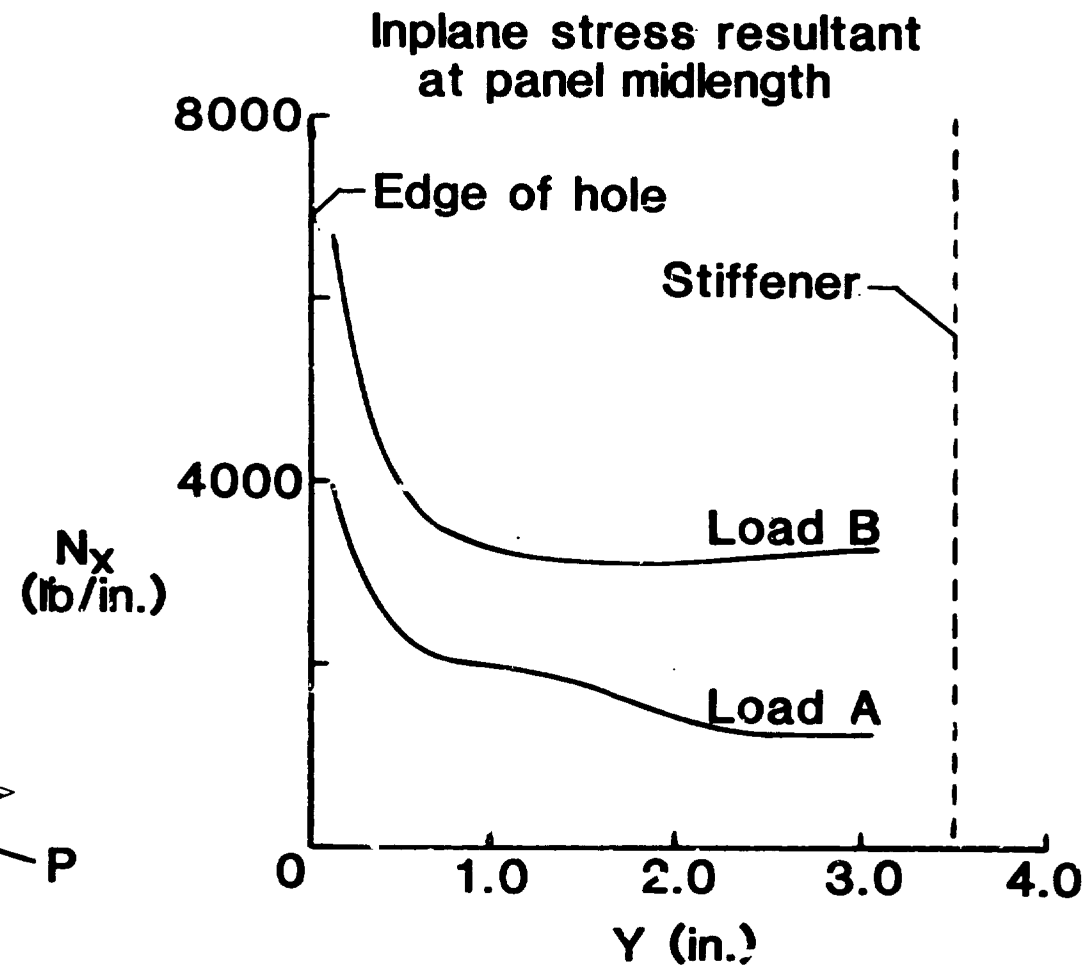
The discontinuous stiffener leads to an eccentric loading condition which causes large out-of-plane displacements to development near the hole from the onset of loading. Because of this coupling between the inplane and out-of-plane displacements, no linear equilibrium path exists.

GLOBAL NONLINEAR RESPONSE PREDICTION



Deformed geometry





GLOBAL NONLINEAR RESPONSE PREDICTION

An oblique view of the deformed geometry for the last calculated solution is shown in the lower left portion of the figure. Longitudinal inplane stress resultant distributions for two values of the applied load as a function of distance from the hole, as shown on the right of the figure, indicate high inplane stresses and a high stress gradient near the hole.

These high inplane stresses and stress gradients coupled with the large out-of-plane displacements and the free edge of the hole may cause material nonlinearities, local failures, and/or delaminations to develop in order to provide local stress relief mechanisms (like plasticity in metal structures) near the hole and blade stifferer. However, an accurate prediction of the effects of these mechanisms on the global nonlinear response requires a more complex local progressive failure analysis for laminated composite structures than is generally available.

STATUS AND ADDITIONAL TASKS

Status

- Finite element model developed and verified
- Global nonlinear response predicted
- Required modeling detail identified for stress gradient near the hole for an unstiffened panel

Additional tasks for focus problem

- Perform multi-level 2-D analysis (refined, local 2-D model)
- Apply appropriate failure criterion
- Perform multi-level 3-D analysis (refined, local 3-D model)

STATUS AND ADDITIONAL TASKS

The overall strategy for this study is to predict the global nonlinear response using the complete global model and then to construct a refined, local 2-D model for a small distance away from the hole. The global nonlinear response has been predicted for the focus problem as indicated on the previous slides. The tasks that remain for the focus problem include performing the multi-level analysis and applying a failure criterion. The multi-level analysis will involve applying the displacements and rotations from the global nonlinear solution to a refined local 2-D model. Using the refined local 2-D model with these imposed deformations, the state of stress at a small distance away from the edge of the hole will be determined. In addition, a three-dimensional model near the hole will be required for an accurate determination of the through-the-thickness state of stress (i.e., normal and transverse shearing stress distributions). The use of 3-D elements within a 2-D model will also require a strategy for the transition or blending of the two models.

NEAR-TERM CSM RESEARCH THRUSTS

(1 to 3 years)

- Solution strategies for nonlinear mechanics problems
- Error analysis with adaptive mesh refinement
- Multibody dynamics of flexible structures
- Concurrent algorithms for transient dynamics
- Concurrent sparse matrix utilities

Application studies

Composite wing and fuselage subscale models

Space structures deployment

NEAR-TERM CSM RESEARCH THRUSTS
(1 TO 3 YEARS)

Over the next 1 to 3 years, the methods research thrusts will be directed toward developing solution strategies for nonlinear mechanics problems that have been defined by the previous application studies. Emphasis will be given to error sensing and control in determining accurate stress distributions in composite structures. Error analysis with adaptive mesh refinement involves calculating the solution error and automatically refining the mesh in areas of large errors. As such, the method is capable of generating its own mesh and assures that the results are within some specified error limits. The activity in multibody dynamics of flexible structures will be fully defined and the computational difficulties will be identified (see ref. 23). Concurrent sparse matrix utilities and algorithms for transient dynamics will be developed and incorporated in the NICE/SPAR system on the FLEX/32.

The application studies will focus on the local/global stress analysis of composite wing and fuselage subscale models. Space structures deployment is currently being considered for the focus problem area for the transient dynamics activity.

LONG-TERM CSM RESEARCH PROGRAM

(3 to 5 years)

- Methods for applications of national interest
- Dynamic and thermal analyses
- Finite element system architectures for multiprocessor computers
- Analysis research complements experimental program

LONG-TERM CSM RESEARCH PROGRAM
(3 TO 5 YEARS)

The long-term (3-5 years) CSM research program will be similar in philosophy to the near-term program. Structural analysis methods will be developed for applications of current national interest (e.g., vehicle crashworthiness, hypersonic aircraft). Emphasis may shift from local/global stress analysis to dynamic and thermal analysis. Concurrent algorithms will be developed for matrix algebra and for the solution of problems in nonlinear structural mechanics. Studies will be carried out to define superior software architectures for structural analysis systems which exploit multiprocessor computers. Finally, to ensure relevancy, the program will be carried out in a problem-solving environment in which the analysis methods research will complement experimental programs.

SUMMARY

- Build, enhance, and maintain initial CSM test bed system utilizing existing executive systems and application modules as feasible
- Emphasize applied structural mechanics research to accelerate methods technology transfer to industry
- Develop methodology to exploit advanced architecture computers
- Solve realistic structures problems to define structural analysis needs and evaluate new methods

SUMMARY

The CSM activity at the NASA Langley Research Center is 1 year old and is focusing on specific areas of application.

A joint effort, between Langley in-house personnel and Lockheed Palo Alto researchers, is well underway to develop the initial CSM test bed system NICE/SPAR. As such, the initial CSM software test bed will exploit the software architectural features of the NICE system and will utilize the stable linear structural analysis capabilities of the SPAR finite element analysis code. Both software systems are now in the public domain.

The CSM methods research efforts will emphasize applied structural mechanics research to accelerate the transfer of methods technology to industry. Structural analysis and computational methods that have reached a level of maturity to demonstrate high potential for solving realistic, practical structural problems will be focused on initially.

n-house research efforts are also well underway in developing methodology to exploit advanced architecture computers. The FLEX/32 multiprocessor computer is serving as the initial CSM hardware test bed for concurrent processing research.

The objectives of the CSM activity include defining structural analysis needs and developing and evaluating new structural analysis methods. The approach being used by the CSM group to accomplish those objectives is to solve realistic, practical structural problems.

The new CSM activity should provide the opportunity to conduct advanced structural analysis research that exploits new and future hardware developments and will serve as a foundation for the next generation structural analysis system.

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16. Abstract

Complex structures being considered by NASA for the late 1980's and early 1990's include composite primary aircraft structure and the space station. These structures will be much more difficult to analyze than today's structures and necessitate a major upgrade in computerized structural analysis technology. NASA Langley has initiated a new research activity in structural analysis called computational structural mechanics or CSM. The broad objective of the CSM activity is to develop advanced structural analysis technology that will exploit modern and emerging computers--such as computers with vector and/or parallel processing capabilities. The three main research activities underway in CSM include: (1) structural analysis methods development, (2) a software testbed for evaluating the methods, and (3) numerical techniques for parallel processing computers.

The motivation and objectives of the CSM activity are presented in this paper followed by a description of the CSM activity. Finally, the current CSM research thrusts, as well as near- and long-term CSM research thrusts, are outlined.

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